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TITLE: Method and arrangment for determination of  
the state of charge of a battery

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## INVENTOR-INFORMATION:

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REPRESENTATIVE-FIGURES: 1

## ABSTRACT:

Method of determining the state of charge soc of a battery, in particular a starting battery of a motor vehicle; the state of charge being calculated, in a first operating range, on the basis of a model calculation in which a measured and a calculated battery voltage U.sub.Batt, U.sub.Batt' are balanced, using feedback.



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Title:

## Method and arrangement for determination of the state of charge of a battery

Document Type and Number:

United States Patent 20030052690

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Abstract:

Method of determining the state of charge soc of a battery, in particular a starting battery of a motor vehicle; the state of charge being calculated, in a first operating range, on the basis of a model calculation in which a measured and a calculated battery voltage  $U_{\text{sub.Batt}}$ ,  $U_{\text{sub.Batt}}$ ' are balanced, using feedback.

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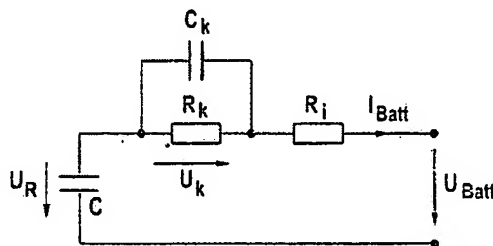
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Representative Image:



Inventors:

Schoch, Eberhard (Stuttgart, DE, US)

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324/433

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## Foreign References:

Date Code Application Number  
Nov 1, 2000 DE 10056969.2

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## Claims:

What is claimed is:

1. A method of determining the state of charge soc of a battery, in particular a starting battery of a motor vehicle, wherein, in the presence of a first operating range of the battery, the state of charge is calculated on the basis of a model calculation, in which a measured and a calculated battery voltage  $U_{\text{sub.Batt}}$ ,  $U_{\text{sub.Batt}}$  are adjusted, using feedback.
2. The method according to claim 1, wherein the first operating range is assumed if a battery current or discharging current is greater than a minimum battery current  $I_{\text{sub.Batt,min}}$  or a minimal battery current.
3. The method according to claims 1 or 2, wherein an off-load voltage  $U_{\text{sub.R}}$  from which the state of charge soc of the battery is derivable is calculated on the basis of the model calculation.
4. The method according to one of the preceding claims, wherein the state of charge soc of the battery is calculated according to a function of the formula  $\text{soc} = f(U_{\text{sub.R}}) = (U_{\text{sub.R}} - U_{\text{sub.R,min}}) / (U_{\text{sub.R,max}} - U_{\text{sub.R,min}})$ .
5. The method according to one of the preceding claims, wherein in the presence of a second operating range of the battery, the state of charge is determined on the basis of a measurement of the battery current and an off-load voltage calculated or estimated last, in particular in the presence of the first operating range.
6. Method according to one of the preceding claims, wherein the second operating range is assumed when the battery current is less than or equal to the minimum battery current  $I_{\text{sub.Batt,min}}$ .
7. An arrangement for determining the state of charge of a battery, in particular a starting battery of a motor vehicle, characterized by a monitoring device, in particular a Kalman filter (1), which determines the state of charge of the battery by calculating an off-load voltage in a first operating range of the battery, on the basis of a model calculation in which a measured and a calculated battery voltage are balanced by feedback; and which determines the state of charge of the battery in a second operating range, on the basis of a measurement of the battery current and an off-load voltage calculated or estimated last, in particular in the presence of the first operating range.

## Description:

## FIELD OF THE INVENTION

[0001] The present invention relates to a method and an arrangement for determining the state of charge of a battery, in particular the starting battery of a motor vehicle.

## BACKGROUND INFORMATION

[0002] Several methods are known to determine the state of charge of starting batteries in motor vehicles. Exemplary methods should be noted, which determine the state of charge via the measurable charge-proportional off-load voltage of a battery which has been idle for a longer period of time, typically four to five hours, using current integration and re-calibration. A method of this type is described in German Patent No. 35 20 985. Furthermore, model-based methods should be noted, which make it possible to determine the off-load voltage and therefore also the state of charge derivable from this off-load voltage, for a battery under load via adaptation of a model to the actual battery using the aid of sensor variables, such as battery voltage, battery current, and/or battery temperature.

[0003] The above-mentioned methods are relatively simple to implement; however, they result in errors during long operating phases of the vehicles, having relatively short or only few rest periods (e.g. taxi operations), because the state of charge may only seldom be re-calibrated or corrected via a measurement of the off-load voltage.

[0004] Model-based methods, in contrast, do not rely on rest periods for re-calibration, and the implementation of such methods, depending on the complexity of the underlying battery model, is relatively complex.

## SUMMARY OF THE INVENTION

[0005] The present invention intends to provide a simple and less complex battery charge detection system for starting batteries in motor vehicles, in particular batteries which are used in vehicle operations without rest periods, for example in taxi operations.

[0006] According to the present invention, a simple battery model is used for re-calibration of the current integration. Because of the simple model approach having few parameters, the utilized estimation procedure for the state of charge may also be used simultaneously for the estimation of unknown parameters without the need for a separate parameter estimator, as described in German Published Patent Application No. 199 50 919, for example.

[0007] In contrast to known model-based methods for determining the state of charge, which operate with complex battery models covering a wide dynamic range as well as a wide operating range with regard to temperature, current, and state of charge, according to the present invention a model is used which only takes into account time constants on the order of magnitude of minutes and hours. This makes it possible to keep the model simple, having only few parameters to be

determined.

[0008] The described method is advantageously only activated in a valid operating range of the model.

[0009] The first operating range in which the method is implemented is expediently defined as one where a minimum battery current  $I_{\text{sub.Batt,min}}$  is exceeded. The limitation of the model, used according to the present invention, to this operating range, i.e., the discharge range of the battery is acceptable with regard to applications for monitoring a minimum state of charge and in practice produces satisfactory results.

[0010] Off-load voltage of the battery from which the battery condition is derivable is advantageously calculated on the basis of the model calculation. Such relationships between off-load and state of charge of the battery are known per se and do not require further explanation.

[0011] Battery condition  $soo$  is expediently determined according to a function of the following formula

$$soo = f(U_{\text{sub.R}}) = (U_{\text{sub.R}} - U_{\text{sub.R,min}}) / (U_{\text{sub.R,max}} - U_{\text{sub.R,min}}) \quad (1)$$

[0012] Where  $U_{\text{sub.R,min}}$  and  $U_{\text{sub.R,max}}$  represent the minimum and maximum off-load voltages, respectively, according to the acid density values for a dead and a fully charged battery provided by the battery manufacturer.

[0013] According to a particularly advantageous embodiment of the present invention, the determination of the state of charge is carried out on the basis of a measurement of the battery current and a latest calculated or estimated off-load voltage  $U_{\text{sub.R0}}$  if a second operating range of the battery is present. If the current integral is formed according to formula  $Q = -\int I_{\text{sub.Batt}} dt$ , it is possible to calculate in this way an instantaneous off-load voltage  $U_{\text{sub.R}}$  according to an equation of the formula  $U_{\text{sub.R}} = U_{\text{sub.R0}} + Q/C$ . Here it is also possible to calculate the instantaneous state of charge on the basis of equation (1) mentioned above.

[0014] It is expediently assumed that a second operating range is present if the battery current is less than the minimum battery current  $I_{\text{sub.Batt,min}}$ .

[0015] Because of the distinction that is made between the two operating ranges mentioned, where  $I_{\text{sub.Batt}} > I_{\text{sub.Batt,min}}$  applies for the first range, and  $I_{\text{sub.Batt}} \leq I_{\text{sub.Batt,min}}$  applies to the second range, an adequate assessment of the state of charge across the entire battery operating range is possible.

[0016] Additional advantages of the present invention arise from the following description of preferred embodiments.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 shows an electrical equivalent circuit diagram of a battery.

[0018] FIG. 2 shows a schematic block diagram to illustrate the battery charge detection system provided according to the present invention.

#### DETAILED DESCRIPTION

[0019] An electrical equivalent circuit diagram of a battery with which the method according to the present invention is applicable is illustrated in FIG. 1. Here capacitor  $C$  describes the almost linear relationship between charge  $Q$  of the battery and off-load voltage  $U_{\text{sub.R}}$  of the battery. Via capacitor  $C_{\text{sub.K}}$  and resistor  $R_{\text{sub.K}}$ , concentration overvoltage  $U_{\text{sub.K}}$  emulates the dynamics of the acid density compensation between the plate pores and the free acid volume. Internal resistance  $R_{\text{sub.i}}$  of the battery includes the ohmic resistances of electrodes and electrolyte as well as the transition resistance of the double layer between electrodes and electrolyte. Finally,  $I_{\text{sub.Batt}}$  indicates battery current or discharging current and  $U_{\text{sub.Batt}}$  indicates battery voltage.

[0020] The method according to the present invention is explained further with reference to FIG. 2. A battery is indicated here using reference symbol 2. Battery 2 has a battery current  $I_{\text{sub.Batt}}$  and a battery voltage  $U_{\text{sub.Batt}}$  which are measured. As illustrated, battery current  $I_{\text{sub.Batt}}$  is input into a model calculation. Adjusted with a calculated or estimated battery voltage  $U_{\text{sub.Batt}}$ , battery voltage  $U_{\text{sub.Batt}}$  is adjusted and is likewise input into the model as an input quantity.

[0021] The state of charge of the battery is determined using off-load voltage value  $U_{\text{sub.R}}$  calculated in this manner, as further explained below.

[0022] First, it is assumed that battery current  $I_{\text{sub.Batt}}$  is greater than minimum battery current  $I_{\text{sub.Batt,min}}$ , i.e., the battery is in its discharging operating range. In this operating range, in order to estimate off-load voltage  $U_{\text{sub.R}}$ , concentration overvoltage  $U_{\text{sub.K}}$  as well as internal resistance  $R_{\text{sub.i}}$ , a monitor is utilized, for example in the form of a Kalman filter 1 (dashed-line frame). For this purpose the utilized model is adjusted by feeding back the error  $U_{\text{sub.Batt}} - U_{\text{sub.Batt}}$  between the measured and calculated battery voltage. If, for example, parameters  $C$ ,  $R_{\text{sub.K}}$  and  $C_{\text{sub.K}}$  are unknown they may also be included in the estimation after a battery replacement.

[0023] As mentioned before, model adjustment only takes place at the operating points relevant for model validity, i.e., for

[0024]  $I_{\text{sub.Batt}} > I_{\text{sub.Batt,min}}$  (discharging current  $> 0$ ). In this case it means that a value  $k = k_{\text{sub.0}} = U_{\text{sub.Batt}} - U_{\text{sub.Batt}}$  is input into the model calculation.

[0025] In the other operating points for which  $I_{\text{sub.Batt}} \leq I_{\text{sub.Batt,min}}$  applies, the feedback of the error into the model calculation is interrupted, i.e.,  $k$  is set equal to 0. In this second operating range, off-load voltage  $U_{\text{sub.R}}$  is calculated using current integral  $Q = -\int I_{\text{sub.Batt}} dt$  and off-load voltage  $R_{\text{sub.0}}$  is estimated last, in particular in the first operating

range, according to the equation  $U_{sub.R}=U_{sub.R0}+Q/C$ .

[0026] In both operating ranges, off-load voltage value  $U_{sub.R}$  resulting from the calculation is subjected to another mathematical operation, in order to obtain battery condition soc (State of Charge). The battery condition is expediently determined according to an equation of the formula

$$soc=f(U_{sub.R})=(U_{sub.R}-U_{sub.R,min})/(U_{sub.R,max}-U_{sub.R,min}).$$

[0027] As already mentioned,  $U_{sub.R,min}$  and  $U_{sub.R,max}$  indicate the minimum and maximum off-load voltages for the acid density values of a dead and a fully charged battery, according to the battery manufacturer.

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